

Constraining the Timing of Dry Gas Formation: Insights from re-Os and Apatite Fission Track Geochronology from South Guizhou (China)

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Abstract

The Paleozoic strata of Southern China are a key target of oil and gas exploration. Reservoirs of the petroleum system of the South Guizhou depression record a complex evolution since the Early Palaeozoic forming live petroleum, pyrobitumen and dry gas. Petroleum in the depression is widely represented as both solid bitumen and pyrobitumen. The bitumen is considered to have formed at the time of initial oil generation, with the pyrobitumen formed from alteration of the bitumen during the formation of dry gas. Here, we apply the rhenium-osmium (Re-Os) isotope system on bitumen and pyrobitumen in Kaili and Majiang palaeo-reservoir and the apatite fission track analysis on Xuefeng uplift to establish the absolute generation age of oil and dry gas in the petroleum system, respectively. The bitumen from Kaili palaeo-reservoir has a low vitrinite reflectance ($R_o < 1.0$), and possesses ~ 1.5 - 4.3 ppb Re and ~ 76 - 206 ppt Os. The Re-Os isotope data yield a date of ~ 429 Ma, with an initial $^{187}\text{Os}/^{188}\text{Os}$ (O_{si}) value of ~ 0.8 . The pyrobitumen from the Majiang area has a high vitrinite reflectance value ($R_o > 2.0$), and possessing ~ 4.9 - 8.4 ppb Re and ~ 98 - 498 ppt Os. The Re-Os isotope data yield a Re-Os date of ~ 60 Ma, with an O_{si} of ~ 1.5 . The apatite fission track ages range from ~ 70 to ~ 120 Ma with $P(\chi^2)$ values > 0.05 and the mean track lengths vary from 12.7 - 13.2 mm. The Re-Os bitumen date is in excellent agreement with previous studies (basin modelling) indicating that the initial crude oil generation time occurred during the Early Silurian. The formation of pyrobitumen within the South Guizhou depression is known to have accompanied dry gas generation during the late stages of petroleum evolution. Previous studies (GC-MS, fluid inclusion analysis and basin modelling) suggest that pyrobitumen formed during the Late Cretaceous Yanshan Orogeny, though the absolute timing is current unsupported by radiometric dating. The time-temperature thermal history modelling of the apatite fission track lengths indicate significant tectonic uplift between 110-80Ma. The agreement of apatite fission track and Re-Os dates suggests; 1) the transformation of bitumen to pyrobitumen resets the Re-Os isotope systematics (also observed for TSR), 2) provides the best estimate for the timing of pyrobitumen formation and by inference the timing of dry gas formation, and 3) provides additional timing constraints on the final stages of tectonic events of the late Yanshan Orogeny.